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ORIGINAL RESEARCH

Toxicology

Use of the online poisons information database TOXBASE and admissions rates for poisoned patients from emergency departments in England and Wales during 2008 to 2015

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Abstract

Background: The impact of poison information services on patient care in hospital, particularly decisions on whether to admit patients after initial attendance at an emergency department (ED), is unclear. In the United Kingdom, the vast majority of poisons information is provided by use of the online poisons information database, TOXBASE. We investigated the relationship between rates of hospital access to TOXBASE and rates of poisoning admissions from EDs in England and Wales to begin to address the interactions between use of poisons information and patient management as reflected by hospital activity.

Methods: Data were obtained on attendances and admissions due to poisoning for individual National Health Service (NHS) Trusts in both England and Wales, together with data on the overall number of accesses to TOXBASE for drugs (pharmaceuticals and drugs of abuse), from 2008 to 2015. Rates of TOXBASE access and admissions per poisoning attendance in London were clearly different to the rest of England and Wales; London was therefore analyzed separately. Negative binomial generalized additive models were fit, incorporating an interaction effect, for accesses, attendances and admissions to check for variability according to hospital size. Additional models were then fit to assess whether there was any variation in association of overall TOXBASE use with rates of admission for 6 key drug subgroups: antidepressants, paracetamol, antipsychotics, opioids (including all medicines, but excluding heroin), heroin and non-opioid drugs of abuse.

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Results: Rates of TOXBASE use per Trust increased across the study period by 39.3% (95% confidence interval [CI] = 34.1%, 44.8%) in England and 76.9% (24.7%, 151.0%) in Wales, showing an increase in TOXBASE use which was substantially greater than the increase in poisoning attendances. Admission rates exhibited seasonality, with lower rates in January and February, increasing by 2.0% (1.0%, 3.1%) in England and 5.8% (5.5%, 5.9%) in Wales toward the middle of the year. The initial model fit indicated that the average proportion of poisoning patients admitted increased with both increasing attendances and increasing TOXBASE use (England and Wales overall, $P < 0.0001$; England and Wales excluding London, $P < 0.0001$; London, $P < 0.0001$). In England and Wales overall, and in London alone, increased TOXBASE access to non-opioid drugs of abuse advice was associated with a significant decrease in admissions (England and Wales, −0.15% [−0.29%, −0.01%] [$P = 0.032$]; London, −1.02% [−1.53%, −0.50%] [$P < 0.0001$]). In contrast, increased access to heroin advice was associated with a significant increase in admissions in London (+2.03% [+0.11%, +3.99%] [$P = 0.034$]). Increasing access to TOXBASE for paracetamol advice was associated with lower admissions in England and Wales (England and Wales, −0.11% [−0.23%, −0.01%] [$P = 0.036$]; England and Wales excluding London, −0.18% [−0.30%, −0.06%] [$P = 0.001$]) but higher admissions in London (+0.52% [+0.03%, +1.01%] [$P = 0.035$]).

Conclusions: We have shown that greater overall use of TOXBASE by hospitals is associated with a higher proportion of poisoning attendances being admitted. Interestingly, looking at particular drug groups, we found significant associations in both directions between overall TOXBASE use and rates of admission for some drug groups. The current methodology is unable to determine whether such decisions might be appropriate or not. Mixed-methods research is now required to gain a better understanding of how provision of poisons information affects decisions within the ED.

KEYWORDS
drugs of abuse, hospital activity analysis, pharmaceuticals, poisons information

1 | INTRODUCTION

1.1 | Background

Poisons information services aim to improve the care of patients with suspected or confirmed poisoning. They may prevent unnecessary hospital presentations (attendances) and are intended to improve triage (decision whether to admit the patient to hospital or discharge from the emergency department) and care of patients who do present to hospital. When used by the public or primary care services, provision of poisons information reduces attendances at emergency departments and hospital admissions in both North America and the United Kingdom.[1,2]

In the United Kingdom, the public is unable to access poisons information directly from poisons information centers. The National Health Service's (NHS) introduction of telephone health information lines for the general public in the early 2000s led to the need for a single authoritative approach to poisons information provision for both primary and secondary care services.[3] The UK National Poisons Information Service had launched its online clinical database TOXBASE in late 1999; it was subsequently adopted as the primary source of poisons information for all healthcare services across the United Kingdom.[4,5] TOXBASE is used routinely in the management of poisoned patients, providing information, not only on the potential toxicity and treatment of compounds, but also the dose thresholds for toxic effects and required duration and nature of clinical monitoring. The database is written and regularly updated by the National Poisons Information Service clinical staff and has an editorial team with specialist advisors and based on national and international published advice. It can be searched for generic and common brand name products, particularly medications. It also contains data on all types of poisoning. It is the agreed standard of care in the United Kingdom. Where additional information is required, healthcare workers call a single national phone number to be connected with poison information specialists and clinical toxicologists at 1 of 4 National Poisons Information Service poisons information centers.

Since 1999, use of TOXBASE has increased by >600% and continues to increase year by year. In 2017–2018, there were over 625,000 individual log-ons in the United Kingdom to the database, accessing in excess of 1.6 million product (agent) entries. Most (60%) came from hospitals, although 30% came from primary care and ambulance services.[6] Most hospital enquiries come from emergency departments; TOXBASE accesses account for the vast majority of National Poisons Information Service contacts from such departments (354,678 in 2016–2017 compared to <11,000 telephone enquiries). For this reason, we concentrated our analysis on TOXBASE use.

1.2 | Importance

Exploring how poisons information services impact patient care in hospital is challenging. Assessing how poisons information affects triage and handling within hospital emergency departments themselves is an important step in understanding, and auditing this interaction is key to improving patient care and the use of poisons services in acute hospitals. This is an important issue if poisons services are to be used optimally and developed to respond to the needs of emergency physicians. This project was undertaken as a first step in understanding how current services are used, and how this might vary across the United Kingdom.

1.3 | Goals

The aim of this project was to evaluate the impact of poisons information services on physician behavior. This is complicated, because hospital activity varies both seasonally and geographically. In addition, use of the TOXBASE database has increased over time.[7] In England and Wales (England and Wales), routine data are available on attendances at emergency departments, with the broad clinical area of reason for attendance described (eg, poisoning), and the proportion of these attendances that are admitted.[8,9] Hospital admissions activity is coded using ICD10, but this coding is not yet applied to attendances.

In this study, we used routinely collected data on TOXBASE accesses from individual NHS Trusts (hospitals) to these pharmaceutical (drug) products on TOXBASE and compared these to attendances, and admissions to wards from the ED, from 2008–2015. Most TOXBASE accesses (83%) from hospitals relate to pharmaceutical (drug) products, including drugs of abuse. Using these data, we have explored the relationship between frequency of overall use of TOXBASE and changes in rates of admission as a proportion of attendances. In this way, we hoped to begin to understand how the use of online poisons information services in the United Kingdom might interact with clinician behavior as reflected by hospital activity and admissions in order to design future studies. An epidemiological study of this design shows associations, which can then be the focus for further studies; it cannot establish causation. As online information systems are increasingly used in medicine this project may also inform others in the field.

The Bottom Line

Use of poison information services in emergency departments may impact admission decisions. Although greater TOXBASE use in England and Wales was associated with admission for poisoning overall, there was a decrease in admission for non-opioid drugs of abuse and acetaminophen.

2 | METHODS

2.1 | Design

Data on the number of admissions and attendances for poisoning in England and Wales for the period January 2008 to December 2015 were obtained from the Health and Social Care Information Centre (HSCIC; https://digital.nhs.uk/) and from the NHS Wales Informatics Service (http://www.wales.nhs.uk/nwis/home). These data were then linked with data on the number of accesses made to the TOXBASE database. For Wales, this was a straightforward task of linking by hospital name. The linkage for the English data were more difficult, because in some cases the hospital activity data were provided at individual hospital level and in others it was provided at the NHS trust level (an administrative unit), amalgamating data from 2 or more hospitals. For consistency, all English hospital-level data were aggregated up to NHS Trust level, which were linked with the relevant hospitals in the TOXBASE data set.

2.2 | Setting

This study was conducted using data available from routine NHS data sources on attendance and admissions from hospital emergency departments in the United Kingdom. We also assessed overall usage of TOXBASE pharmaceutical product (agent) entries (including drugs of abuse) as well as 6 common medicines and recreational drug groups: antidepressants, paracetamol, antipsychotics, opioids (including all opioid medicines but excluding heroin), heroin, and non-opioid drugs of abuse. For simplicity, we refer to these together as "Drugs." Heroin was assessed separately from opioids due to the major differences in its supply and usage across the United Kingdom.

2.3 | Selection

The data set used contained all data available to us for the study period in England and Wales. Because poisoning attendances were not consistently recorded in the early days of these NHS data systems, some data were excluded from these analyses. Attendance reasons were not recorded in Wales until April 2009, so all Welsh data prior to that

date were eliminated from the analysis. In England, the reasons for attendance at EDs (ie, poisoning) were not always consistently recorded in some Trusts, and this was further complicated by merger of hospitals into Trusts within the study period. Together, this resulted in some large data gaps for poisoning attendances and resultant sharp drops in the number of poisoning attendances recorded. Data within these periods of unreliable recording were eliminated on a case-by-case basis resulting in 4986 rows of data out of 13,990 rows being omitted from the analysis; this amounted to only 2.8% of the total number of attendances at A&E for poisoning (1,255,412). As a consequence, data on 37.3% of TOXBASE accesses and 37.4% of hospital admissions could not be used indicating that the data quality issue only affected emergency attendances to hospital. In total, the analysis included data from 116 trusts out of 143 in England and 13 out of 17 in Wales.

Data obtained from HSCIC in England were subject to the suppression of small values (between 1 and 5) to keep individual patients unidentifiable. To address this issue, we used a technique whereby missing values were imputed empirically using a Bayesian model incorporating seasonality and long-term trend to estimate results in the range of 1–5. Use of this method made allowance for hospital size (and therefore workload) that meant that missing values for those hospitals that were larger and consequently had mostly complete data were more likely to be imputed as 4 or 5, whereas those locations with a large number of missing values were likely to be smaller hospitals and so more likely to have smaller imputed values.

This study did not require approval by a UK Research Ethics Committee because the UK Health Research Authority has declared that ethical approval is not needed for research studies that use information collected routinely by any UK administration (England, Wales, Scotland and Northern Ireland) as part of usual clinical care, provided this information is passed to the researchers in a fully anonymized format.

2.4 | Analysis

The seasonal and long-term trends in the rate of poisoning admissions and the rate of TOXBASE accesses were explored using generalized additive models, which allow for smoothly varying relationships through time. The smooth terms and parameters in these models were estimated via an iterative process. At each step, the terms were estimated based on the response values minus the current estimates of each other term in the model, so that the values being used to estimate the components were overall centered around zero but still retained some pattern that is to be estimated, herein referred to as the centered response. It is the final values of this iterative process that will be presented and interpreted as the trends in the model.

The first model in this article examined the appropriateness of an interaction term in examining the effect of TOXBASE use on admissions. The model fit was of the form shown below:

$$E(\log(y_i)) = \log(a_i) + \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{1i} x_{2i} + f(t_i) + g(m_i). \quad (1)$$

In this model, $E(\log(y_i))$ is the expected log number of admissions, and $\log(a_i)$ is the log number of poisoning attendances. The result of this is that this model provides insight into the rate of poisoning admissions per poisoning attendance, rather than the number of admissions due to poisoning. We wanted to incorporate some measure of hospital size in the model, hence the total number of attendances is represented by x_{1i}. The rate of TOXBASE access per attendance is represented in the model using x_{2i}, and $x_{1i}x_{2i}$ denotes an interaction between hospital size and TOXBASE accesses, which will account for differences in the effect of TOXBASE access by hospital size. The final 2 terms represent the overall ($f(t_i)$) and seasonal ($g(m_i)$) patterns in the rate of admissions per attendance. Positive values of β_1 or β_2 indicated that admissions grow with attendances or accesses, whereas negative values indicated a decrease in admissions with attendances or accesses respectively. The coefficient β_3 of the interaction term indicated how admissions change with attendances for different levels of TOXBASE usage.

The above model was used as a starting point for the analysis and was simplified where appropriate. These data exhibited over-dispersion, a common artefact in count data, where the variance is larger than the mean. This does not hold with the assumption of equal mean and variance distribution made by use of the Poisson distribution. In order to account for this over-dispersion, a negative binomial model was used.

Similar models were then used to summarize how the rate of admission varied in an average trust, with respect to the proportion of accesses to the 6 aforementioned drug sub-groups. These models took a simpler form as outlined in the following equation:

$$E(\log(y_i)) = \beta_0 + \beta_1 x_i. \quad (2)$$

Here, y_i is the proportion of attendances due to poisoning that resulted in admission within each Trust, whereas x_i is the proportion of accesses made to the relevant drug group. Each drug group was assessed independently, but the results will be presented as a whole. In this analysis, we expect the coefficient β_1 to be negative when increasing proportions of accesses are associated with a decreasing proportion of admissions.

Temporal changes were explored by fitting models for rates of TOXBASE access and rates of admission by trust, through time. The models were of the form:

$$E(\log(y)) = \beta_0 + \beta_1 \text{ year}. \quad (3)$$

where y represents either the rate of access to TOXBASE or the rate of admission due to drugs poisoning. The coefficient β_1 was extracted for admissions and accesses for each trust to give a measure of the rate of change of TOXBASE use and admissions over time by trust.

Due to the nature of the data, each model was fit on the log scale, meaning that differences estimated from any of the above models are presented as multiplicative percentage changes. The results

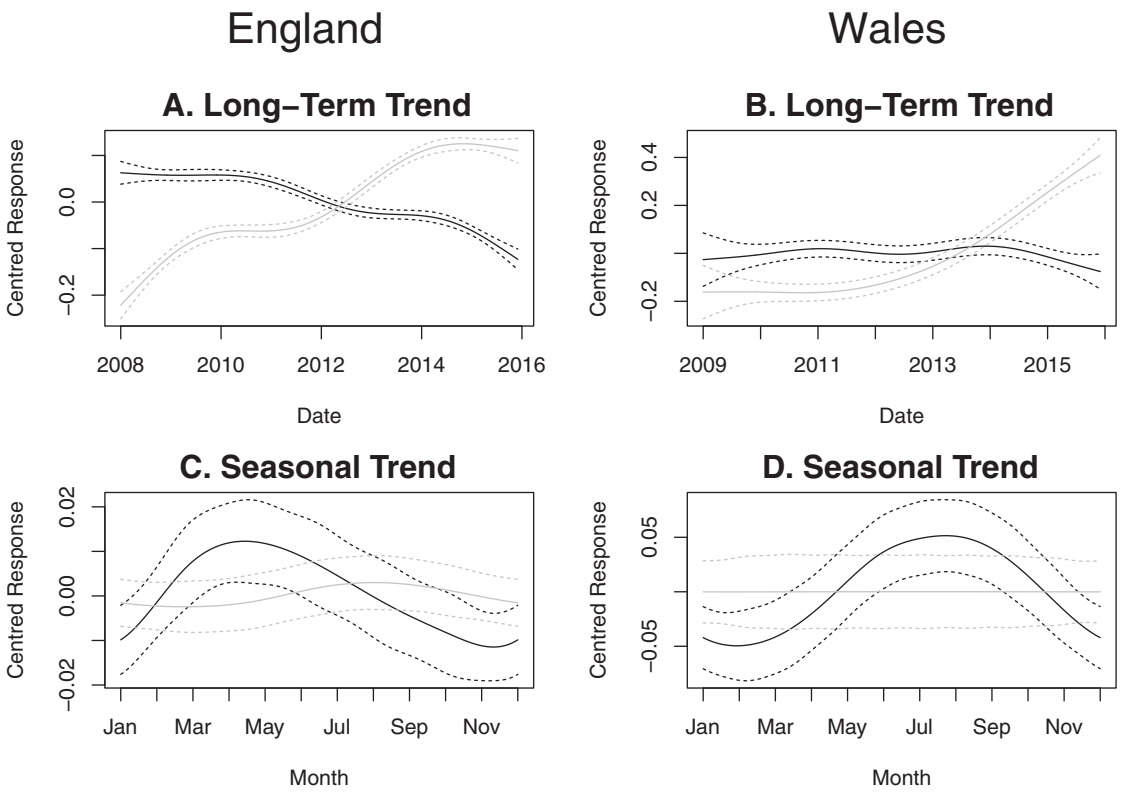

FIGURE 1 Plots showing the long-term and seasonal trends for TOXBASE accesses in grey (—) and poisoning admissions in black (—) for England (A and C) and Wales (B and D). The dashed lines represent 95% confidence intervals. For ease of comparison the data are shown related to a centered response

section will also describe raw data, estimated regression coefficients and model predictions where appropriate.

3 | RESULTS

During the period studied, after accounting for issues with data recording, there were 1,220,857 attendances at hospital emergency departments in England and Wales that were coded as due to poisoning. During the same period, 581,368 patients were admitted (46.5 per 100 attendances) due to overdose involving Drugs, and the relevant products pages within TOXBASE were consulted 2,629,846 times (2.15 accesses/attendance).

3.1 | Long-term and seasonal trends

The seasonal and long-term trends in the rate of admissions due to drugs poisoning and the rate of TOXBASE accesses/month are shown in Figure 1 as a centered response. In England, the average Trust had 1262 attendances, 639 admissions (50.6% of attendances), and 2205 TOXBASE accesses (1.75/attendance) in 2008. In 2015, the average number of attendances had increased to 1754 (39.0% increase), with 762 admissions (19.2% increase; 43.4% of attendances) and 4165 TOXBASE accesses (88.9% increase; 2.37/attendance). In Wales, the respective figures for 2009 were 425 attendances, 207 admissions (48.7% of attendances) and 686 TOXBASE accesses (1.61/attendance); by 2015, these had risen to 641 (50.8% increase), 291 (40.6% increase; 45.4% of attendances) and 2239 (326% increase; 3.49/attendance), respectively.

Using the statistical models to look at the overall trend, the proportion of attendances admitted decreased by 17.0% (14.3%, 19.6%) in England between 2008 and 2015 compared to the non-significant decrease of 4.9% (−23.0%, 13.2%) in Wales between 2009 and 2015. TOXBASE usage, as a rate per poisoning attendance, in the statistical models increased over the study period, by 39.3% (34.1%, 44.8%) in England and 76.9% (24.7%, 151.0%) in Wales.

We assessed whether the admission rate and the rate of TOXBASE accesses per poisoning attendance showed seasonal variability. The proportion of attendances admitted showed statistically clear seasonal variability, with a peak in May in England and August in Wales (Figure 1); the seasonal peak in summer is equivalent to a small increase in admissions of 2.0% (1.0%, 3.1%) in England, and 5.8% (5.5%, 5.9%) in Wales from January. Seasonal variability also occurred in the volume of TOXBASE use as we have previously reported[7]; however, examining TOXBASE accesses per poisoning attendance to control for the seasonal variability in attendances shows that there is no residual seasonality in TOXBASE access.

TABLE 1 Total number of attendances, poisoning-related admissions and TOXBASE accesses, in addition to the proportion of attendances admitted and the rate of TOXBASE access per attendance for each region between 2008 and 2015

Region	Attendances (n)	Poisoning-Related Admissions (n)	Proportion of admissions	TOXBASE accesses (n)	Rate of TOXBASE access per attendance
North West	241,883	119,105	0.492	553,592	2.289
Yorkshire and the Humber	183,263	82,582	0.451	387,800	2.116
South East	163,955	84,843	0.517	328,887	2.006
London	150,815	42,808	0.284	246,445	1.634
West Midlands	124,769	57,051	0.457	239,882	1.923
East of England	95,617	53,290	0.557	250,536	2.62
South West	82,753	45,160	0.546	168,682	2.038
East Midlands	73,586	41,455	0.563	189,344	2.573
North East	56,303	32,460	0.577	130,550	2.319
Wales	47,913	22,614	0.472	134,128	2.799
Total	1,220,857	581,368	0.476	2,629,846	2.154

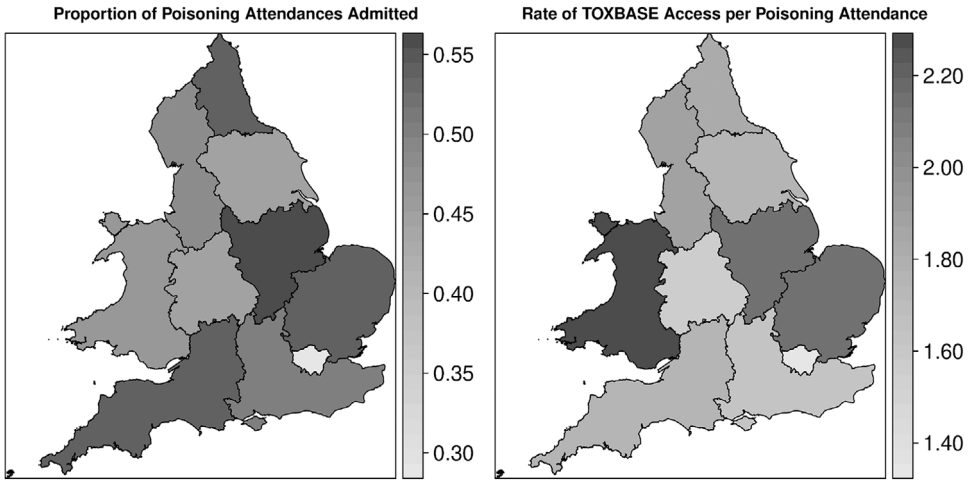

FIGURE 2 "Heat" maps showing the variation in the proportion of poisoning attendances admitted and the rate of TOXBASE accesses per poisoning attendance. Darker areas represent higher activity

3.2 | Regional variability

We then investigated regional variability in the proportion of poisoning attendances admitted and in the rate of TOXBASE accesses per poisoning attendance across England and Wales. This was done by examining NHS Regional level maps of the data. These NHS Regions were changed during the period covered by the study to a much larger number of smaller areas run by NHS Clinical Commissioning Groups. For simplicity, we have used the older regional classification. Overall rates of admission and TOXBASE access per attendance were calculated as the total number of admissions or accesses in that region, over the entire period, divided by the total number of attendances due to poisoning in that region over the entire period.

We found there to be little variability in the proportion of poisoning attendances who were admitted, other than for London. Over the entire study period, the proportion of attendances admitted from England and Wales regions outside London ranged from 0.451 in Yorkshire and the Humber region to 0.577 in the North East region (Table 1; Figure 2) compared to 0.284 in London. The rate of TOXBASE accesses per poisoning attendance within England varied from 1.923 in the West Midlands to 2.620 in the East of England, with London again low at 1.634 and Wales high at 2.799 (Table 1; Figure 2).

From these data, it is clear that the pattern of poisoning admissions and TOXBASE accesses is different in London compared to the rest of England and Wales. Specifically, both the proportion of attendances admitted and the rate of TOXBASE accesses per poisoning attendance

TABLE 2 Model coefficients for the effect of hospital attendances, TOXBASE accesses and the interaction of these attendances and accesses on hospital admission due to drugs poisoning for each of England and Wales overall, England and Wales excluding London and London only. These coefficients were estimated after accounting for temporal trends in admissions

	England and Wales overall	England and Wales excluding London	London
Attendances	-2.570×10^{-5} SE 1.57×10^{-6} $P < 0.0001$	-2.069×10^{-5} SE 1.92×10^{-6} $P < 0.0001$	-3.453×10^{-5} SE 3.55×10^{-6} $P < 0.0001$
TOXBASE accesses	0.1107 SE 4.48×10^{-3} $P < 0.0001$	0.1198 SE 4.58×10^{-3} $P < 0.0001$	0.0565 SE 2.04×10^{-2} $P < 0.0001$
Attendances × TOXBASE accesses	4.073×10^{-6} SE 4.52×10^{-7} $P < 0.0001$	2.931×10^{-6} SE 4.76×10^{-7} $P < 0.0001$	8.405×10^{-6} SE 1.77×10^{-6} $P < 0.0001$

TABLE 3 Estimated coefficients for the effect of hospital size (as measured by the total number of attendances) and the rate of access to TOXBASE on the rate of admission due to poisoning per poisoning attendance after accounting for temporal trends

	England and Wales overall	England and Wales excluding London	London
Total attendances	-1.719×10^{-5} SE 1.28×10^{-6} $P < 0.0001$	-1.354×10^{-5} SE 1.55×10^{-6} $P < 0.0001$	-2.185×10^{-5} SE 2.49×10^{-6} $P < 0.0001$
Rate of access to TOXBASE	0.1447 SE 0.0025 $P < 0.0001$	0.1435 SE 2.58×10^{-3} $P < 0.0001$	0.1438 SE 9.14×10^{-3} $P < 0.0001$

are lower in London than in the other regions. One possible explanation for the difference in London may be relative excess of medical students, but this would be expected to cause more TOXBASE accesses per admission, not the fewer we saw. This observed difference may also be related to some London hospitals following different protocols for treating poisoned patients, and this prompted the decision to further assess trends in 3 different ways: England and Wales overall, in England and Wales without London and London alone.

3.3 | Interaction models

We then assessed the relationship between rate of TOXBASE use per poisoning attendance and the rate of admissions due to drugs poisoning per poisoning attendance. This was initially done using the interaction model outlined in Equation 1, which took account of the effect of overall attendances on the rate of admissions, to investigate whether the effect of TOXBASE use varied depending on hospital size. We found that the interaction term in the model was 4.073×10^{-6} (standard error (se) 4.515×10^{-7}), $P < 0.001$. This implies that were large hospitals to increase their rate of accesses to TOXBASE the predicted increase in the admission rate is proportionately higher than in a smaller hospital which increases its access rate. However, the magnitude of this effect is minor as evidenced by the estimated coefficient, given the magnitude of the coefficient of the main effect of the TOXBASE access rate (Table 2).

For the data overall, the model including the interaction term resulted in 75.4% of the variance in the observed data being explained—this was only a marginal improvement over the model excluding the interaction term, which had 75.2% variance explained. These results were similar for the data excluding London and for London individually. This indicates that the interaction effect does not contribute a great deal to the fit of the model, and for simplicity, the model excluding this interaction will be presented here.

We found that the rate of admissions due to poisoning (per poisoning attendance) tended to decrease as hospital size increased, as indicated by the negative estimate of the coefficient in the first row of Table 3. This decrease is such that for every 100 additional attendances the rate of admissions per poisoning attendance would decrease by ≈0.2%.

In addition, there was an increase in the rate of poisoning admissions with an increasing rate of access to TOXBASE. This increase was such that for every additional TOXBASE page accessed per poisoning patient, there was a 15.6% (95% confidence interval [CI] = 15.0%, 16.1%) increase in the rate of poisoning admissions per poisoning attendance. The size of this effect was similar across all 3 of the regional configurations examined (see Table 2; positive coefficient in the second row).

These models were additionally fit for each year to investigate whether the relationship between TOXBASE use and attendances was stable over the period of the study. With the exception of 2008, during which there were no observations for Welsh hospitals, and English

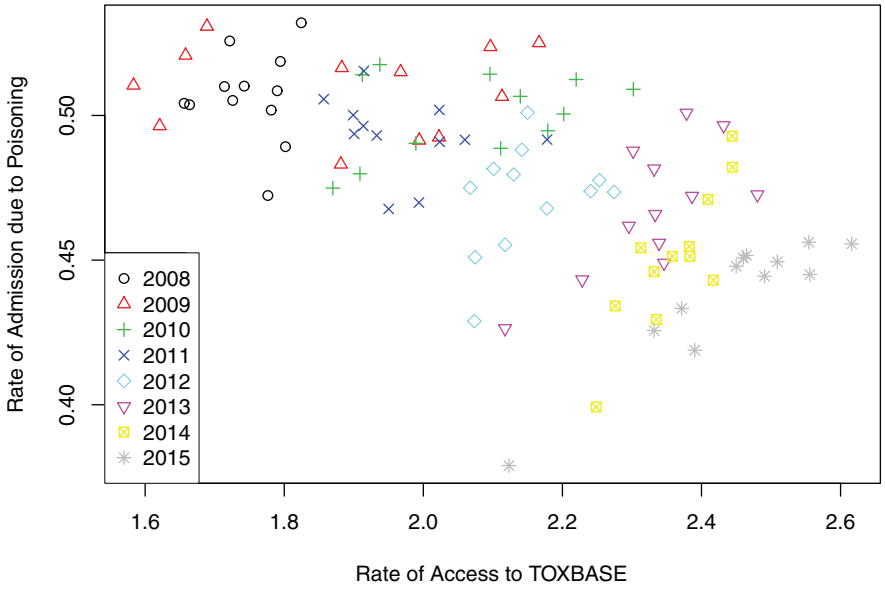

FIGURE 3 Plot showing the relationship between the rate of poisoning admissions per poisoning attendance and the rate of TOXBASE use per poisoning attendance. Groups of points are separated by colour to extract the relationship by month within each year

data not particularly well recorded, there was very little variation in the estimated coefficients by year (Supporting Information Table S1).

The positive association between TOXBASE use and admissions described by the model coefficients seems counterintuitive, given the opposing trends in the rate of admission and the rate of TOXBASE use seen in Figure 1. Further exploration of this is shown in Figure 3, which plots the rate of admissions per poisoning attendance against the rate of TOXBASE access per poisoning attendance. The data have been aggregated over trusts, so that each point in the plot corresponds to a month of data. The points are colored based on which year the data were observed in, and it can be seen that points observed in earlier years tend to be on the left-hand side of the plot, with later years sitting on the right-hand side of the plot. There is, overall, a decreasing trend in these observations, which is due to the overall temporal pattern, where the average rate of admission has decreased over time.

Examining individual groups of points, it can be seen that, particularly in recent years, there is positive correlation between the rate of admission and the rate of TOXBASE access per poisoning attendance. It is this which is driving the positive coefficient for TOXBASE use in the models above (Tables 2 and 3).

Models were fit for each individual trust for the rate of TOXBASE accesses and the rate of admissions due to drug poisoning against year to get an estimate of the annual rate of change. These trust-level coefficients were used to find those trusts that had the largest decrease in TOXBASE use through time, the largest increase in TOXBASE use through time, and the smallest change in TOXBASE use through time. The top 5 in each case were taken, and the rate of admission due to poisoning was plotted against the rate of TOXBASE access per poisoning attendance. The coefficients for the relationship between admission and access rates in those with the largest increase, the smallest change, and the largest decrease in TOXBASE use were (coefficient [se]): 0.049 (0.020), 0.109 (0.022) and 0.203 (0.027), respectively. This indicates that for those hospitals in which TOXBASE use has decreased most, the rate of admissions reduced more than the comparative increase in admissions in those hospitals whose TOXBASE use increased most, further emphasising an interaction between TOXBASE use and admission rates with poisoning.

This finding is suggestive of a link between TOXBASE use and triage admission decisions for poisoned patients. However, this analysis cannot determine whether TOXBASE use is changing decisions on admission or whether more severe cases that require admission result in more TOXBASE use. To explore this aspect in more detail, we undertook modelling of common drug groups, to compare the patterns of TOXBASE agent accesses for these drugs with the overall proportion of poisoning patients admitted in NHS Trusts, which might lead to a better understanding of the impact of TOXBASE. We reasoned that, if these drug groups varied in their effects on admission, this might indicate an effect deriving from TOXBASE advice.

3.4 | Drug group specific modelling

We did not have access to diagnostic coding for attendances or admissions, preventing us from relating drug-specific TOXBASE accesses to attendances and admissions for that same drug. However, we obtained drug group TOXBASE access data for 6 important drug groups (antidepressants, paracetamol, antipsychotics, opioid medicines [excluding heroin], heroin, and non-opioid drugs of abuse, Table 4) and compared it with the overall proportion of poisoning admissions per Trust. Across groups, we noted regional variation in TOXBASE accesses, with London often being high or low for the proportion

TABLE 4 Number of accesses to TOXBASE entries on pharmaceuticals overall and to selected drug classes during the study period by UK areas

	England and Walesoverall(%)	England and Wales excluding London(%)	London(%)
All drug accesses	2,184,507	1,985,033	199,474
Antidepressants	370,657 (17.0)	341,922 (17.2)	28,735 (14.4)
Paracetamol	323,308 (14.8)	294,449 (14.8)	28,859 (14.5)
Non-opioid drugs of abuse	150,040 (6.87)	133,252 (6.71)	16,788 (8.42)
Opioids	141,069 (6.45)	130,612 (6.58)	10,457 (5.24)
Antipsychotics	125,698 (5.75)	113,912 (5.74)	11,786 (5.91)
Heroin	15,786 (0.72)	13,992 (0.70)	1,794 (0.90)

Each cell contains the number of accesses. The percentage of accesses is displayed in parentheses where appropriate.

TABLE 5 Individual effects of accesses to TOXBASE on the rate of change in admissions as presentations for 6 common drug sub-groups for England and Wales combined, England and Wales excluding London, and London trusts only

	England and Walesoverall	England and Wales excluding London	London
Antidepressants	+0.01% (−0.11%, +0.14%)	+0.04% (−0.09%, +0.17%)	−0.21% (−0.71%, +0.30%)
Paracetamol	−0.11% (−0.23%, −0.01%)[a]	−0.18% (−0.30%, −0.06%)[a]	+0.52% (+0.03%, +1.01%)[a]
Non-opioid drugs of abuse	−0.15% (−0.29%, −0.01%)[a]	−0.04% (−0.19%, +0.10%)	−1.02% (−1.53%, −0.50%)[a]
Antipsychotics	+0.00% (−0.19%, +0.20%)	+0.07% (−0.14%, +0.28%)	−0.49% (−1.21%, +0.24%)
Opioids	−0.02% (−0.22%, +0.17%)	+0.03% (−0.17%, +0.23%)	−0.59% (−1.41%, +0.23%)
Heroin	+0.44% (−0.15%, +1.03%)	+0.16% (−0.45%, +0.78%)	+2.03% (+0.11%, +3.99%)[a]

The values shown are the percentage change in admissions for every increase of 1 attendance. [a]Significant effects.

of accesses to each drug group (Table 4, Supporting Information Table S1).

Models were fit to assess the effect of TOXBASE access rates on admissions for these drug groups. The effects of the drugs categories on admission were in some cases quite different between London and elsewhere in England and Wales (Table 5). In England and Wales overall, and in London alone, increased accesses to TOXBASE advice on non-opioid drugs of abuse (as a proportion of all TOXBASE accesses) were associated with a statistically significant decrease in admissions per attendance (England and Wales, −0.15% [−0.29%, −0.01%], $P = 0.032$; London, −1.02% [−1.53%, −0.50%], $P = 9.2 \times 10^{-5}$). Increased access to heroin advice was associated with a significant increase in admissions in London (+2.03% [+0.11%, +3.99%], $P = 0.034$) but not elsewhere in England and Wales. Increased access to the paracetamol TOXBASE entry was associated with a significant reduction in admissions in England and Wales overall and England and Wales excluding London (England and Wales, −0.11% [−0.23%, −0.01%], $P = 0.036$; England and Wales excl. London, −0.18% [−0.30%, −0.06%], $P = 0.001$) but increased admissions in London (+0.52% [+0.03%, +1.01%], $P = 0.035$).

4 | DISCUSSION

In this paper, we examined the interaction between hospital activity—specifically the decision to admit a poisoned patient attending the emergency department—and the level of use of the online poison information service TOXBASE. We used statistical models for this analysis, to account for underlying national changes over time of the use of the TOXBASE database, poisoning attendances, and admissions from the emergency department to hospital wards. The United Kingdom runs a health care system (NHS) that is free at pointofcare and is fully funded by taxation. There are no private facilities included in this analysis and effectively none in the United Kingdom in any case. Patients may, as elsewhere, self-present to an ED, present after consultation with a doctor/pharmacist or generic health information telephone line (NHS111 in UK) or after calling an ambulance directly. Although these data do not allow us yet to understand the interaction of poisons information and management at an individual patient level, being designed to give an overview of the interactions between database use and triage at a national, regional and drug category level across England and Wales, they are essential for describing and understanding

the situation before conducting any further mixed-methods research analysis.

The use of an internet database by clinicians is not equivalent to telephone enquiries, in that >1 access may be made to an individual database drug entry for individual patients. Thus, access rates do not equate to patients, and more complex poisoning cases may result in more database accesses than simpler ones. It is not possible for us to differentiate duplicate enquiries from single enquiries about a patient. Because the number of telephone calls from UK hospitals to the National Poisons Information Service were orders of magnitude less than TOXBASE use, only 3% of the National Poisons Information Service enquiries coming from hospital emergency departments are by telephone, they are unlikely to impact this analysis. The approach we have used is intended to address this by overall modelling of total database activity, and patient handling is unlikely to be unique to individual hospitals or regions of the United Kingdom. We included large numbers of TOXBASE enquiries and related them to hospital activity.

These models show clear interactions on a population level between the usage of poisons information services and hospital activity. For any given level of activity (number of poisoning attendances), the number of patients admitted directly relates to the number of times TOXBASE is accessed. Higher rates of TOXBASE access are associated with higher rates of poisoned patient admissions, especially in larger hospitals. These interactions seemed stable across all years studied, apart from 2008 when data from the Welsh system was unavailable and English data markedly incomplete (Supporting Information Table S1). Comparing hospitals based on their change in TOXBASE use over time indicated that, in the hospitals where the usage of TOXBASE decreased most over the study period, there was a larger relative decrease in the rate of admissions compared to the increase in admissions in those hospitals whose TOXBASE use increased. These analyses further support interactions between TOXBASE use and admission rates as they show clear relationships between hospital activity and changes and usage of poisons information in TOXBASE.

It is possible that higher TOXBASE use is due to more complex cases being seen and admitted, and the database being accessed more often by multiple clinical teams involved in the treatment of these patients. However, because this methodology does not determine causality, we cannot ascertain if the increased admission rate per attendance associated with increased TOXBASE use represents improved patient management or is caused by an unknown confounder. Although the increased use of a poison information facility could affect admissions, further work is required to assess if the increases in admissions we observed are clinically appropriate. Unfortunately, national attendance data are not coded accurately enough for us to account for the influence of attendance case-mix on proportion of cases admitted.

We addressed this problem in attendance coding by reasoning that analysis of TOXBASE accesses to groups of different pharmaceuticals could act as a surrogate for case-mix. If use of TOXBASE was entirely driven by hospital activity, then the relationship between admissions and ED accesses to relevant TOXBASE pages would be consistent. In contrast, if TOXBASE influenced clinical decisionmaking, one would expect the relationship between specific TOXBASE access and admissions to be more complex—the situation revealed in this analysis. Interestingly we found both positive and negative relationships between admissions and TOXBASE accesses for different drug groups and in different regions. Increased rates of access to non-opioid drugs of abuse were associated with reduced admissions, whereas increased access to paracetamol information was associated with increased admissions in London but reduced admissions in the rest of England and Wales. Thus, although it might be assumed that staff might be familiar with common poisoning such as paracetamol and only use TOXBASE for difficult patients, there are several points in the management pathway where reference to TOXBASE might be useful, such as reviewing blood test results and decisions on further treatment or discharge. Increased access to heroin information was associated with an increase in admissions in London only.

These findings are compatible with clinical decisionmaking being related to TOXBASE advice with the observed data being what one might expect if poisons advice aided triage of some patient groups, enabling early safe discharge of some, and requiring further observation of others, with admission. Although we cannot definitively confirm this due to lack of data on presentation medication ingestion, we believe this the most plausible explanation.

The data on paracetamol are unexpected and may relate to some clinicians accessing TOXBASE for all paracetamol poisoning due to the complexity of advice since the 2012 regulator's new advice on paracetamol management,[10] and in particular use of local management protocols, such as we have previously described.[11]

The patterns of attendances and TOXBASE use are different in London compared to the rest of England and Wales. These findings are in line with the regional differences we have previously found in paracetamol poisoning admissions[12] and with different patterns of use of drugs of abuse across the United Kingdom.[13] London is the NHS Region with least TOXBASE use and fewest admissions for poisoning. Although the current data on hospital attendances are insufficiently detailed to allow any further exploration of this finding, possible explanations may include the high proportion of English medical schools based in London (7 of 25 total) and a difference in experience or confidence of ED staff. Other possibilities are differences in epidemiology of poisoning, local practice or the way TOXBASE is used between London and elsewhere in England and Wales. Further research will require more data on individual case-mix and severity, as well as direct observational studies of TOXBASE use. However, these differing patterns and trends within different UK regions are compatible with a direct effect of poisons information on clinician behavior.

Going forward, we believe these data have the potential to be used for audit of performance of individual units as a tool for public health, and to do that, optimally, we would need data on presentation ingestions to be included, which is not presently the case. This has also prevented analysis of admissions as a proportion of presentations for specific drugs. This is one reason we are unable to assess the reasons for different patterns in London and the rest of the United Kingdom.

Such information would also better support policy in managing poisoning in the United Kingdom.

5 | LIMITATIONS

The paper is limited by our inability to show causality. However, because we show that the rates of admission are related to TOXBASE use at Trust level, and these effects are significant at the national level, the association has face validity.

Data had to be excluded from the analysis due to incompleteness or to inconsistency in the way attendance reasons were recorded. We are dependent on hospital coding for our analyses, with discharge coding being used in the case of admission. A proportion of coding errors are likely to have occurred in all hospitals but are unlikely to have affected our conclusions; furthermore, detailed analysis of discharge coding has suggested these are generally >95% accurate.[14]

We have not considered the effect of National Poisons Information Service's telephone information services, which are available 24/7 to support clinicians managing more complex poisoning. However, because at least 97% of poison information enquiries from EDs come via the internet and TOXBASE, differences in telephone call numbers cannot explain the significant differences we have observed. It is also likely that most triage decisions occur after review of TOXBASE advice and not after a phone call, because these tend to deal with specific treatment advice.[6]

The hospital attendance and admission data did not contain information on the agents involved, which may have confounded the analysis, particularly for smaller hospitals that receive fewer cases and do not tend to handle complex cases poisoning. However, as the data in England pertain to trusts, differences in case mix should have been averaged out. The imputation of small numbers could potentially add error, but this is minimized due to the inclusion of many of these smaller hospitals within the larger Trusts used in our analysis.

Finally, in the drug group-level analysis, access to specific drug groups on TOXBASE was used to describe the trend in drugs poisoning overall. A better comparison could be made if data were available on admissions and attendances due to poisoning by each specific drug group. However, even if the data were available, the number of admissions and attendances would be small, requiring a large amount of data suppression to maintain patient confidentiality, markedly reducing usability.

6 | CONCLUSIONS

In summary, we have shown that increased hospital use of an internet-based poisons information database, TOXBASE, is associated with an increase in overall admission rates overall, but rates of access to particular drug groups differ in their relationships with admission rates. These findings suggest a possible direct effect of TOXBASE on clinician behavior and patient management decisions and highlight the potential use of point-of-care internet poisons information systems. Further mixed-methods research is required to obtain better evidence on how TOXBASE is used in EDs and how it might affect clinical practice.

AUTHOR CONTRIBUTIONS

KP and CR formulated and carried out the analysis presented. ME and ES contributed data and advice relating to TOXBASE. DNB and KP drafted the manuscript and all authors contributed to its revision.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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